Interview Summary

In re reconsideration of	:	Customer Number: 45462
HOU, DEYANG	:	
Application No. 10/597,000;	:	Group Art Unit: 3752;
Filed: April 28, 2008	:	Examiner: JONAITIS, JUSTIN

For: MIXED-MODE FUEL INJECTOR WITH A VARIABLE ORIFICE

Mail Stop Inter Partes Reexam
Attn: Central Reexamination Unit
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

All participants:
(1) JUSTIN JONAITIS (Examiner) (3) DEYANG HOU (Applicant)
(2) LEN TRAN (Supervisory Patent Examiner)

Date of Interview: 22 July 2009
Type: Telephonic
Exhibit shown or demonstration conducted: No
Claims discussed: 1-23.
Identification of prior art discussed: U.S.Patent #4,350,301 to Erwin et al.
Agreement with respect to the claims was reached.

Applicant disclosed the differences in figure 2&5 of the Ervin versus the applicant's invention. The applicant explained that the injector of Ervin cannot produce two different spray patterns (from a single injector). Applicant explains that the pintle (134) would only generate the multijet (spray) flow, but not the conical spray flow. The applicant and examiners further discussed how the mechanism of applicant's invention closes the micro-variable-orifice in order to produce the different spray patterns.

The examiners agreed on withdrawing the rejections on claims 1-23.

The examiner suggested a description of seal surface (2 on FIG 2 in application), without adding substance matter, will make the claims more clear. The Applicant agrees. An amended claims (minor amendments in red font) is listed on page 4-7.

A fuller description of the Applicant's discussion on the technical matters is as page 2-3.

1. Claims 1 are valid claims based on following facts:

- In re claim 1, the said invention gives a fuel injector which is composing a nozzle body and a needle valve which has a converging-diverging conical head, and most importantly, composing a micro-variable-circular-orifice which has means for discharging fuel in variable sprays of conical and conical-multi-jet shapes through said micro-variable-circular-orifice by lifting said needle valve at different magnitudes.
- Ervin et al. did not disclose such a micro-variable-circular-orifice which has means for discharging fuel in variable sprays of conical and conical-multi-jet shapes through said micro-variable-circular-orifice by lifting said needle valve at different magnitudes.
- The embodiment by Ervin in FIG. 2 and FIG. 5 are <u>separate embodiments</u> which gives a separate conical and multi-jet spray pattern, no embodiment of a design for combined two spray patterns were given by Ervin in a single injector;
- <u>FIG. 2 from Ervin can not be modified to produce multi-jets as it may be suggested by anyone,</u> <u>since the orifice is at the same time serves as a sealing surface,</u> no fuel channels can be added at the orifice or above the orifice of Ervin's design without invalidating the seal function. Sealing function is a key function for fuel injector; an injector without sealing surface is invalid. In contrast, Hou's design provides a separate seal surface (2 on FIG. 2) which is independent of the orifice portion, which can always effectively seal fuel.
- FIG. 5 in Ervin's design is not a working model, which can not be introduced into practice, due to the seal surface formed by a couple of sliding surfaces which can never practically seal fuel due to expansion (an expansion of few micron meters is sufficient for leaking fuel under high pressure) once subjecting to fuel pressure;
- Ervin's design is fundamentally different from Hou's design in terms of sealing surface (shown in Hou's FIG 2 (2)) and combined spray patterns. Hou's design ensures the injector can sustain high injection pressure for sate-of-the-art advanced combustion. Ervin's design can not sustain high pressure.

- The said invention by Hou provides a unique innovative working design with simple structure for producing variable spray patterns using a single needle valve in a single injector. It has been first introduced into physical prototyping and practice, it is an industrial applicable invention;
- Claims 3-5, 17, & 19-20 will follow the same arguments as Claim 1.

2. Claims 2 are patentable due to the same arguments for claim 1, more specifically:
    - Claim 2 differs from claim 1 in that an injector has 'plurality micro-channels'.
    - Claims 6-16, 18, & 21-23 will follow the same arguments as Claim 1 & 2.

The applicant has searched the related patents listed by patent examiner, and fund none of the prior art can given variable spray patterns through a single injector with a single needle as defined in the patent application 10/597,000. The applicant believes that the said injector is unique and bears inventions and merits not provided by prior arts, it's applicable for industrial applications. It has been introduced into practical application testing.

Respectfully submitted,

Deyang Hou

August 2, 2009

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as our correspondence address.

Claims

1. A mixed-mode fuel injector comprising:

(i) a nozzle body (5) comprising passages for fuel (FP), an inner cylindrical space for receiving a needle valve, and a conical surface (C) close to the tip (7) of the nozzle body for guiding a spray of fuel;

(ii) a needle valve (1), which has a converging-diverging conical head for guiding a spray of fuel and which is movable back and forth and received in said nozzle body, wherein said needle valve is at a biased closing position with its seal surface (2) being pressed against nozzle body (5) to block fuel flow, or an opening position defined by driving means; and

(iii) a micro-variable-circular-orifice (4) comprising a variable circular ring aperture between said needle valve and said nozzle body and at least one micro-channel (6), such that fuel is dischargeable in variable sprays of conical and conical-multi-jet shapes through said micro-variable-circular-orifice by lifting said needle valve at different magnitudes.

2. A mixed-mode fuel injector according claim 1, wherein the micro-variable-circular-orifice (4) further comprises a plurality of micro-channels (6).

3. A mixed-mode fuel injector according to claim 1 or 2, wherein the conical surface (C) has a single conical surface.

4. A mixed-mode fuel injector according to claim 1 or 2, wherein the conical surface (C) is an integrated conical surface having two or more conical surfaces with different conical angles connected together.

5. A mixed-mode fuel injector according to claim 1 or 2, wherein the conical surface (C) is a diverging curved surface.

6. A mixed-mode fuel injector according to claim 1 or 2, wherein the needle lift for the opening position is approximately in the range of 0-300μm, the needle head diameter is approximately in the range of 0.8-3.5mm, and the angle between the centerline of the nozzle body (5) and the inner conical surface (C) at the nozzle body tip (7) is approximately in the range of 35-75 degree.

7. A mixed-mode fuel injector according to claim 2, wherein the plurality of micro-channels (6) is on the said conical surface (C) with cross sections that are one or more of semi-circles, arcs, triangles, trapezoids or other polygons.

8. A mixed-mode fuel injector according to claim 2, wherein the needle head (3) remains at least partially received within the tip (7) as the needle valve (1) is moved back and forth between the biased closing position and opening position such that when fuel is injected through the micro variable aperture (4) between the needle head and said conical surface of the nozzle body, fuel is also injected through the multiple micro-channels (6), the upper surface of the needle head and the conical surface serve as guiding surfaces for fuel sprays.

9. A mixed-mode fuel injector according to claim 7, wherein there are about 4-20 micro-channels with the cross-section of semi-circles with the diameters approximately in the range of 50-300μm.

10. A mixed-mode fuel injector according to claim 7, wherein there are about 4-20 micro-channels (6) having a cross-section other than semi-circles with the maximum dimension approximately between 50-400μm.

11. A mixed-mode fuel injector according to any of claims 2 to 10, wherein the sizes of said micro-channels (6) are the same.

12. A mixed-mode fuel injector according to any of claims 2 to 10, wherein the sizes of the micro-channels (6) are different depending on specific needs of atomization.

13. A mixed-mode fuel injector according to any of claims 2 to 12, wherein the said micro-channels (6) are distributed on or under the conical surface (C) so that they can be open channels or closed channels.

14. A mixed-mode fuel injector according to claim 2, has a plurality of micro-channels underneath the said conical surface (C), forming a sac-hole or valve-covered-orifice multi-hole type injector through blocking the circular aperture by the needle head at a predefined needle-lift range.

15. A mixed-mode fuel injector according to claim 2, wherein different shapes of fuel sprays are generated by changing the magnitude of lift of said needle valve (1) and the needle valve is arranged within the nozzle body (5) so that, at low to medium injection loads, fuel is mainly

injected through the variable circular aperture between the needle head (3) and conical surface (C) of nozzle body (5), thus mainly forms a conical shape spray, while at high injection loads, fuel is injected through both the variable circular aperture between the needle head and nozzle body and the micro-channels (6), thus forms a mixed-mode conical-multi-jet shape spray, whereby provides different atomization desired by engine combustion at different loads.

16. A mixed-mode fuel injector according to claim 2, wherein different shapes of fuel sprays are generated by changing the magnitude of lift of said needle valve (1) and the needle valve is arranged within the nozzle body (5) so that, at low to medium injection loads, fuel is mainly injected through the variable circular aperture between the needle head (3) and conical surface (C) of nozzle body, thus mainly forms a conical shape spray, while at high injection loads, the needle head can completely or partially block the variable circular aperture, whereby fuel is fully or mainly injected through the micro-channels (6), which can be open channels or closed channels depending on penetration needs, thus mainly forms conventional multi-hole sprays at high loads, whereby provides different penetration desired by engine combustion at different loads.

17. A mixed-mode fuel injector according to claim 1 or 2, wherein the fuel channel (FC) between the needle valve (1) and the nozzle body (5) is of converging-diverging shape and by lifting said needle valve at different magnitudes, the minimum cross-section is at the sealing surface (2) during the early stage of fuel injection, the minimum cross- section is at said micro-variable-circular-orifice (4) or at the sealing surface (2) during the middle stage of fuel injection, and the minimum cross-section is at the sealing surface (2) again during the late stage of fuel injection, whereby it has means of ensuring fine atomization during all fuel injection stages.

18. A mixed-mode fuel injector according to claim 1 or 2, wherein the angle between the centerline of the conical surface (C) and the centerline of the nozzle body (5) is approximately 0-15 degrees, depending on an angle between a centerline of the fuel injector and a centerline of a piston in an engine cylinder.

19. A mixed-mode fuel injector according to any of the preceding claims, wherein the fuel injected is one or more of diesel fuels, gasoline fuels, alternative fuels, mixtures of water and fuels, pure water or liquid exhaust cleaning additives in which case, the fuel injector is a general purpose injector.

20. A mixed-mode fuel injector according to claim 1, wherein the needle valve (1) is passively driven by high fuel pressure which provides said driving means.

21. A mixed-mode fuel injector according to claim 1, wherein the needle valve (1) is actively driven by an actuator which provides said driving means.

22. A mixed-mode fuel injector according to claim 21, wherein the actuator is a solenoid or a piezo actuator.

23. A mixed-mode fuel injector, which has a micro-variable-circular-orifice (MVCO) comprising a variable circular ring aperture and multiple-micro-channels as in claim 2, wherein the MVCO is used as a sole orifice or in-combination with other multi-hole conventional orifice wherein fuel is injected through multiple channels in multi-jets into combustion chamber.